



# **HiLiftPW-3**

## **Overview and Grid Systems**

**Jeffrey Slotnick**  
The Boeing Company

**Gerrit-Daniel Stich**  
NASA Ames Research Center

**3<sup>rd</sup> AIAA CFD High Lift Prediction Workshop**  
Denver, CO, USA  
3-4 June 2017

- **Overview**
  - Organizing Committee
  - Objectives
  - Test Cases
  - Participant Statistics
- **Grid Systems**
- **AIAA Special Sessions**
- **Acknowledgments**

# Organizing Committee

- **Jeffrey Slotnick and Tony Sclafani**  
The Boeing Company
- **Mark Chaffin and Ed Feltrop**  
Textron Aviation
- **Ralf Rudnik**  
DLR – German Aerospace Center
- **Thomas Wayman**  
Gulfstream Aerospace Corporation
- **Yasushi Ito and Mitsuhiro Murayama**  
JAXA – Japan Aerospace Exploration Agency
- **Thomas Pulliam and Cetin Kiris**  
NASA Ames Research Center
- **Chris Rumsey, Beth Lee-Rausch, and Judi Hannon**  
NASA Langley Research Center
- **Carolyn Woerber<sup>†</sup>**  
Pointwise, Inc.
- **Dimitri Mavriplis<sup>\*</sup>**  
University of Wyoming
- **Neil Ashton**  
University of Oxford

\* DPW organizing committee member

† GMGW organizing committee member

- Assess the numerical prediction capability (meshing, numerics, turbulence modeling, high-performance computing requirements, etc.) of current-generation CFD technology/codes for **swept, medium/high-aspect ratio wings in landing/take-off (high-lift) configurations**
- Develop practical **modeling guidelines** for CFD prediction of high-lift flowfields
- Advance the understanding of **high-lift flow physics** to enable development of more accurate prediction methods and tools
- Enhance CFD prediction capability to enable practical **high-lift aerodynamic design and optimization**

## Case 1: Grid Convergence Study

Flow solutions on a series of consistently refined fixed grids are requested to assess grid convergence. At a minimum, flow solutions should be provided for **at least one family of coarse, medium, and fine workshop-provided meshes**. Providing the flow solution for the extra-fine mesh is optional.

### Geometry

The **NASA High Lift Common Research Model (HL-CRM)** is a wing-body high lift system that will be studied in a nominal landing configuration (slat and flaps deployed at 30° and 37°, respectively) without nacelle, pylon, tail, or support brackets.

### Case Parameters and Requirements

#### Case 1a: Full Chord Flap Gap (REQUESTED)

Mach Number	0.2
Alphas	8 and 16°
Reynolds Number based on MAC	3.26 million
Reference Static Temperature	518.67°R (=15.00°C=59.00°F)
Reference Static Pressure	760.21 mmHg (=14.700 PSI)
Mean Aerodynamic Chord (MAC)	275.8 inches full scale
Important Details:	<ul style="list-style-type: none"><li>• The intent here is to analyze the full-scale geometry at wind tunnel conditions. Instead of scaling the geometry down to 10% scale, we are analyzing the full-scale grid in a more viscous fluid. In other words, viscosity in this case is <u>not</u> sea level standard, but is scaled up appropriately, to achieve the desired Re of 3.26 million based on 275.8 inches for the full-scale model.</li><li>• Run simulations FULLY TURBULENT.</li><li>• This configuration is gapped approximately 1" full-scale between the inboard/outboard flaps and between inboard flap and side of body.</li><li>• All simulations are "free air"; no wind tunnel walls or model support systems.</li></ul>

#### Case 1b: Full Chord Flap Gap with Adaptation (OPTIONAL)

Use grid refinement based on automatic solution adaptation and/or solution-guided grid regeneration to perform the required grid convergence study using the parameters from Case 1a.

#### Case 1c: Partially-sealed Chord Flap Gap (OPTIONAL)

Using the flow conditions from Case 1a, provide flow solutions for the medium grid only with a partial chord seal between the inboard and outboard flaps, and between the inboard flap and side of body.

#### Case 1d: Partially-sealed Chord Flap Gap with Adaptation (OPTIONAL)

Use grid refinement based on automatic solution adaptation and/or solution-guided grid regeneration to perform the required grid convergence study using the parameters from Case 1c.

## Case 2: Nacelle Installation Study

Flow solutions are required to assess the effects of adding a nacelle and pylon to the high lift system. At a minimum, flow solutions should be provided for *at least one workshop-supplied medium grid*.

### Geometry

The **JAXA Standard Model (JSM)** is a wing-body high lift system that will be studied in a nominal landing configuration (single segment baseline slat and single segment 30° flap) with support brackets on, and nacelle/pylon on/off. The experiment used a semi-span model with a 60 mm peniche standoff, but requested computations are “free air.”

### Case Parameters and Requirements

#### Case 2a: Nacelle/Pylon OFF (**REQUESTED**)

Mach Number	0.172
Alphas	4.36, 10.47, 14.54, 18.58, 20.59, and 21.57°
Reynolds Number based on MAC	1.93 million
Reference Static Temperature	551.79°R (=33.40°C=92.12°F)
Reference Static Pressure	747.70 mmHg (=14.458 PSI)
Mean Aerodynamic Chord (MAC)	529.2 mm model scale
Important Details:	<ul style="list-style-type: none"><li>• Run simulations FULLY TURBULENT and/or WITH SPECIFIED TRANSITION and/or WITH TRANSITION PREDICTION METHODS.</li><li>• All simulations are “free air”; no wind tunnel walls or model support systems.</li></ul>

#### Case 2b: Nacelle/Pylon OFF with Adaptation (**OPTIONAL**)

Use grid refinement based on automatic solution adaptation and/or solution-guided grid regeneration to provide the required flow solutions using the parameters from Case 2a.

#### Case 2c: Nacelle/Pylon ON (**REQUESTED**)

Using the parameters from Case 2a, provide flow solutions for high lift configuration with the nacelle/pylon assembly ON.

#### Case 2d: Nacelle/Pylon ON with Adaptation (**OPTIONAL**)

Using the parameters from Case 2a, provide flow solutions for high lift configuration with the nacelle/pylon assembly ON using grid refinement based on automatic solution adaptation and/or solution-guided grid regeneration.

## Case 3: Turbulence Model Verification Study **(REQUESTED)**

The purpose of this case is to investigate the consistency in the implementation of turbulence models in a controlled grid-refinement study. The geometry is a 2-D DSMA661 (MODEL A) airfoil (see TMR website <http://turbmodels.larc.nasa.gov/airfoilwakeverif.html>). Case parameters are Mach=0.088, Re=1.2 million based on chord, reference freestream temperature=540°R, angle of attack=0°. This study looks at grid convergence of airfoil forces, as well as behavior of the velocity and turbulent shear stresses in the near wake. The behavior of wakes is relevant to high-lift configurations, because the wakes from upstream elements pass over and often interact with the boundary layers of downstream elements.

Grids from the TMR website ([http://turbmodels.larc.nasa.gov/airfoilwake\\_grids.html](http://turbmodels.larc.nasa.gov/airfoilwake_grids.html)) should be employed, if possible. Participants must run on at least the finest three grid levels provided (1793x513, 897x257, and 449x129). I.e., at least three solutions (on three different successively-refined grids of the same family) are required in order to tell where the solution is headed as the grid is refined. Grid adaption may also be used to demonstrate grid convergence, if possible. However, the airfoil shape is not analytically defined. For this verification study you are asked to run the same turbulence model(s) being run for the other HiLiftPW-3 cases. RUN FULLY TURBULENT. For the SA and SST turbulence models, results are currently provided on the TMR website for comparison. If you are using a turbulence model other than SA or SST, your results will form the basis for future comparisons against other codes with the same model.

# Configuration Information

	Grid resolution level	y+ at walls	Initial wall spacing, $\Delta y$ (normal dist)	Number of cells (points) on trailing edges
<b>Case 1: HL-CRM</b>  $Re = 3.26M$ $C_{REF} = 275.8$ in	Coarse	1.0	0.00175 Inches	4 (5)
	Medium	2/3	0.00117 inches	8 (9)
	Fine	4/9	0.00078 inches	12 (13)
	Extra-Fine <b>OPTIONAL</b>	8/27	0.00052 inches	16 (17)
<b>Case 2: JAXA JSM</b>  $Re = 1.9$ M $C_{REF} = 529$ mm	Coarse <b>OPTIONAL</b>	1.0	0.00545 mm	4 (5)
	Medium	2/3	0.00363 mm	8 (9)
	Fine <b>OPTIONAL</b>	4/9	0.00242 mm	12 (13)
	Extra-Fine <b>OPTIONAL</b>	8/27	0.00161 mm	16 (17)



# Datasets

Y Dataset Complete  
I Dataset Incomplete



PID	Author	Model	Code	1a	1b	1c	1d	2a	2b	2c	2d	3	Case 1 committee grid	Case 1 participant grid	Case 2 committee grid	Case2 participant grid	Tecplot Symbol
001.1	Chen	SA	Mflow	I		I		I		I		y	B3		E		A solid
002.1	Ashton	SA	OpenFOAM	I				I		I				d-HLCRM	E		B solid
002.2	Ashton	SA	Star-CCM+	I				I						d-HLCRM	E		B dash
003.1	Zastawny	SST	Star-CCM+	y		y		y		y		y	B3		D		C solid
003.2	Zastawny	SA	Star-CCM+	y								y	B3				C dash
003.3	Zastawny	ke lagEB	Star-CCM+	y								y	B3				C dot-dash
003.4	Zastawny	SST-gamma	Star-CCM+					y							D		C dot-dot-dash
004.1	Glasby	SA-neg	Kestrel/COFFE	I				y				I	B1		C1		D solid
004.2	Eymann	SA	Kestrel	I										participant (?)			D dash
004.3	Nichols	BSL	Kestrel/KCFD	y				y				I	B2		C2		D dot-dash
004.4	Nichols	SA	Kestrel/KCFD	y				y				I	B2		C2		D dot-dot-dash
005.1	Coder	SA-AFT	OVERFLOW					I		I					A		E solid
006.1	Edge	SA-RC-QCR	CFD++	y				y		y		y	B2		D		F solid
006.2	Edge	SA	CFD++									y					F dash
007.1	Michal	SA-QCR	GGNS	y	y	y	y	y	y	y	y	y	B1	special (a-HLCRM)	C1	participant (?)	G solid
008.1	Yasuda	SA-noft2	Cflow	y	y	y	y	y	y	y	y	y	B3	n-HLCRM	D	e-JSM	H solid
009.1	Mor-Yossef	SST-2003	Arion					I							C2		I solid
009.2	Mor-Yossef	SST-2003	Arion					I							E		I dash
010.1	Zore	SA	Fluent									y					J solid
010.2	Zore	SST	Fluent									y					J dash
011.1	Ito	SA-noft2-R	TAS	y				y		y		y	B3		D		K solid
011.2	Ito	SA-noft2-R-QCR2000	TAS	y				y		y			B3		D		K dash
012.1	Li	SA-QCR	CFD++	y		y		y		y		I		e2-HLCRM	C2		L solid
012.2	Li	SA-RC-QCR	GGNS	I		y								e1-HLCRM			L dash
013.1	Konig	LBM-VLES	PowerFLOW					y		y						participant (?)	M solid
014.1	Lofthouse	SARC	Kestrel	y				y		y			B2		C2		N solid
014.2	Lofthouse	SARC+DDES	Kestrel	y				y		y			B2		C2		N dash
015.1	Wang	SA	TRIP	y				y		y		I		participant (?)		participant (?)	O solid
016.1	Pogosyan	RSM-SSG/LRR-w	LOGOS	y				y		y		y	B3			participant (?)	P solid
016.2	Pogosyan	SA	LOGOS	y				y		y		y	B3			participant (?)	P dash
016.3	Pogosyan	SST	LOGOS	y				y		y		y	B3			participant (?)	P dot-dash
017.1	Risley-Settle	SA-neg	TAU					y		I					B		Q solid
017.2	Risley-Settle	SA-neg	TAU					y		y						f-JSM	Q dash
018.1	Moens	SA	elsA	I								y	B2				R solid
019.1	Scalabrin	SA	SU2	y				y		y		y	B3		C2		S solid
020.1	Nichols	Wilcox2006	TENASI	I								I	B3		E		T solid
020.2	Nichols	Wilcox2006	TENASI	I										k-HLCRM			T dash
020.3	Nichols	SST+SAS	TENASI	I				y				y	B3		E		T dot-dash
020.4	Nichols	SST+SAS	TENASI	I				y		I				k-HLCRM		c-JSM	T dot-dot-dash
020.5	Nichols	SAS k-e	TENASI	I								y	B3				T long dash
020.6	Nichols	SAS k-e	TENASI	I										k-HLCRM			T dash 0.8

# Datasets

**Y** Dataset Complete  
**I** Dataset Incomplete



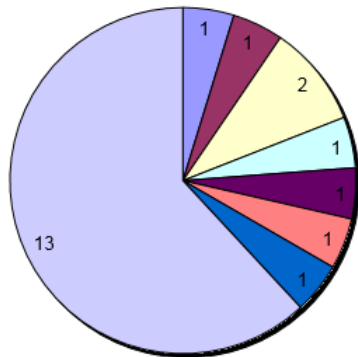
PID	Author	Model	Code	1a	1b	1c	1d	2a	2b	2c	2d	3	Case 1 committee grid	Case 1 participant grid	Case 2 committee grid	Case2 participant grid	Tecplot Symbol
021.1	daSilva	SA	BRU3D	I				y		y		y		d-HLCRM	E		U solid
022.1	Pulliam	SA-RC-QCR2000	OVERFLOW	y		y		y		y			A		A		V solid
022.2	Pulliam	SA	OVERFLOW					y				y			A		V dash
023.1	Yousuf	SA-RC-QCR	BCFD	y				y		y		y		e2-HLCRM	E		W solid
023.2	Yousuf	SA-RC	BCFD									y					W dash
023.3	Yousuf	SA	BCFD									y					W dot-dash
023.4	Yousuf	SST	BCFD									y					W dot-dot-dash
024.1	Tamaki	SA-noft2-R	UTCart					y		y						participant (?)	X solid
025.1	Cimpoeru	SST-V-sust	zCFD	y				I		I		y		participant (?)		participant (?)	Y solid
026.1	Rudnik	SA-neg	TAU	y				y		y		y		p-HLCRM	B		Z solid
026.2	Rudnik	SA-neg	TAU									y					Z dash
026.3	Rudnik	SA-noft2	TAU									y					Z dot-dash
026.4	Rudnik	SA-noft2	TAU									y					Z dot-dot-dash
026.5	Rudnik	RSM-SSG/LRR-g	TAU									y					Z long dash
026.6	Rudnik	RSM-SSG/LRR-g	TAU									y					Z dash 0.8
028.1	O'Connell	LBM-VLES	PowerFLOW	I		I								participant (?)			a solid
030.1	Langlois	Wilcox88	Dragon	y				y				y	B2		E		b solid
030.2	Langlois	Wilcox88	Dragon	y		y		y		y				f-HLCRM		b-JSM	b dash
030.3	Langlois	Wilcox88	Dragon					y							E		b dot-dash
030.4	Langlois	Wilcox88	Dragon					y		y						b-JSM	b dot-dot-dash
030.5	Langlois	SA	Dragon									y					b long dash
030.6	Langlois	SST	Dragon									y					b dash 0.8
030.7	Langlois	Wilcox98	Dragon									y					b dash 0.5
031.1	Brionnaud	WALE	XFlow	I				I		I				participant (?)		participant (?)	d solid
032.1	Jansson	FEM adaptive	Unicorn						I			I				participant (?)	e solid
033.1	Jensen	SA-QCR2000	LAVA	y		y		y		y			A		A		f solid
033.2	Jensen	SA	LAVA							y		y				participant (?)	f dash
034.1	Escobar	SA	SU2	I								y	B3				g solid
035.1	Wurst	SA-noft2	PHASTA	y				y		y		y	B1		C1		h solid
036.1	Luo	SST	FUN3D	I				I		I			B1		C1		m solid
036.2	Luo	SA-neg	FUN3D					I		I					C1		m dash
036.3	Luo	k-kL-MEAH2015	FUN3D					I							C1		m dot-dash
036.4	Luo	SST-GRET	OpenFOAM									I					m dot-dot-dash
036.5	Luo	SA	OpenFOAM									y					m long dash
036.6	Luo	SST (mod)	OpenFOAM					I		I		y				participant (?)	m dash 0.8
039.1	Powell	SA	FUN3D	I				I		I			B2		C2		q solid
040.1	Duque	SA-noft2	OVERFLOW	y									A				r solid

# Statistics - Participants

## HiLiftPW-1

8 Countries

21 Participants

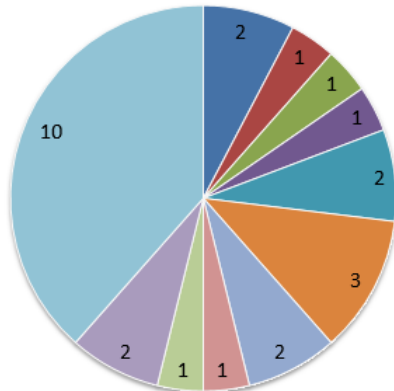


Canada  
France  
Germany  
India  
Japan  
Sweden  
Switzerland  
USA

## HiLiftPW-2

11 Countries

26 Participants

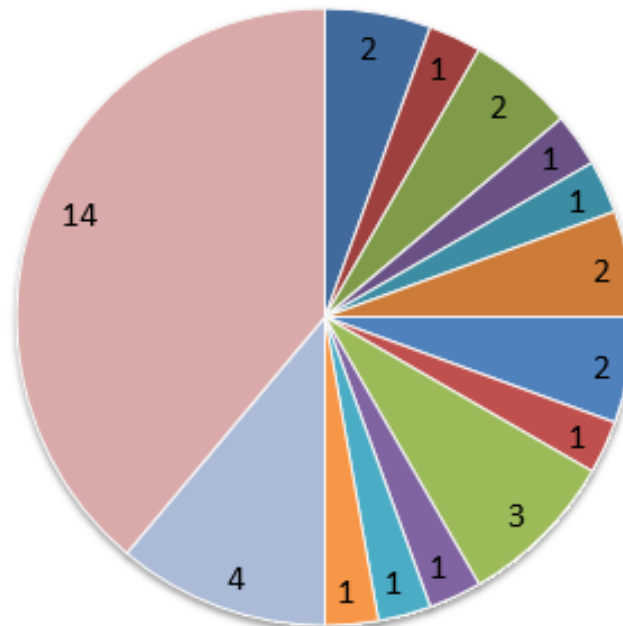


Canada  
China  
Columbia  
France  
Germany  
India  
Japan  
Russia  
Spain  
Sweden  
USA

## HiLiftPW-3

14 Countries

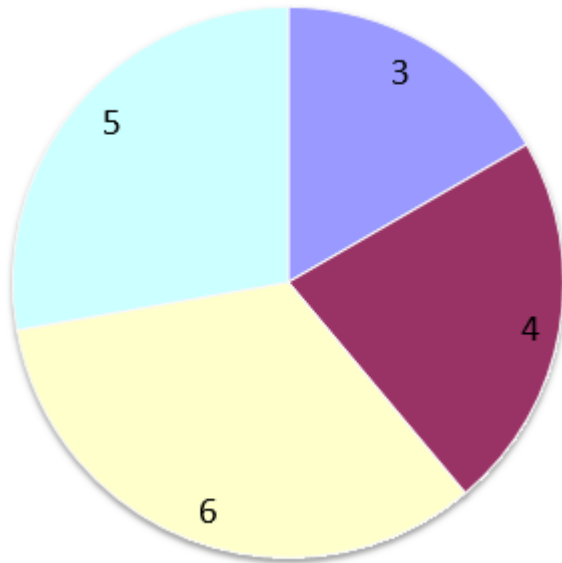
36 Participants



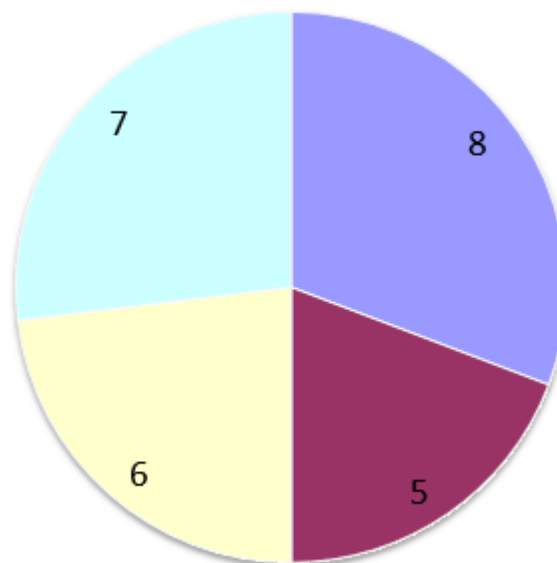
Brazil  
Canada  
China  
Columbia  
France  
Germany  
India  
Israel  
Japan  
Russia  
Spain  
Sweden  
UK  
USA

# Statistics - Organizations

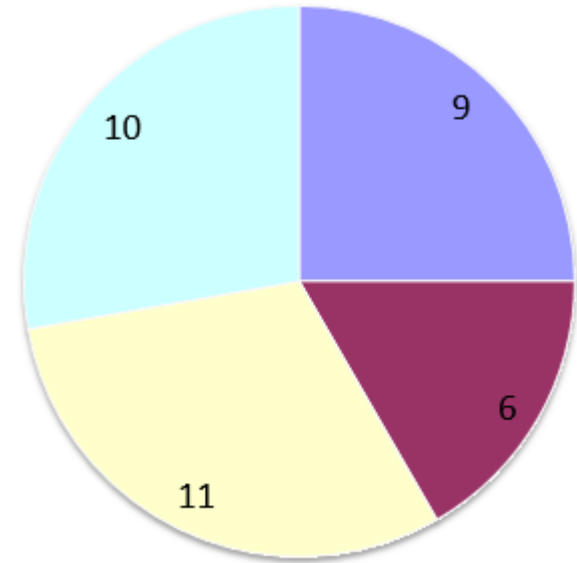
HiLiftPW-1



HiLiftPW-2



HiLiftPW-3



- Academia
- CFD Vendors
- Government Research Labs
- Industry

	HiLiftPW-2	HiLiftPW-3
Number of Test Cases	3 Requested 4 Optional	4 Requested 5 Optional
Number of Datasets	36	78
Total number of Test Case Submissions	84	202

- Significant increase in the amount of data generated by the CFD community.
- Committee needs more time to post-process data and interpret the relevant trends.

- Overview
  - Organizing Committee
  - Objectives
  - Test Cases
  - Agenda
  - Participant Statistics
- Grid Systems
- AIAA Special Sessions
- Acknowledgments

# Gridding Guidelines

- Located on HiLiftPW website:  
<https://hiliftpw.larc.nasa.gov/Workshop3/GriddingGuidelines-HiLiftPW3-v10.pdf>
- Significant update from previous versions
- Attempted to be more specific about cell sizes, spacings, and stretching ratios
- In the end, the document is meant to provide a general guide to grid generation, and not impose hard rules.

# Grid Systems (HL-CRM)

Series	Type	Number of points (M)	Number of cells (M)	Developer	Tool
A	Overset	24, 65, 189, 565	23, 64, 185, 554	NASA Ames	ANSA+ Chimera grid tools
B1	Tetrahedral	8, 26, 70, 206	48, 157, 416, 1228	Pointwise	Pointwise
B2	Mixed (prism dominant)	8, 26, 70, 206	22, 65, 170, 541	Pointwise	Pointwise
B3	Mixed (hex dominant)	8, 27, 71, 208	18, 48, 119, 397	Pointwise	Pointwise
C	Structured point-matched	10, 77, 338	8, 68, 311	GridPro	GridPro

Blue=Coarse

Green=Medium

Black=Fine

Red=X-Fine



# Grid Systems (JSM)

Series	Type	Number of points (M)	Number of cells (M)	Developer	Tool
A	Overset	221, 235	216, 230	NASA Ames	Chimera grid tools
B	Mixed	102, 126	162, 207	DLR	DLR-SOLAR
C1	Tetrahedral	16, 21	96, 124	S/G*	VGRID
C2	Mixed	16, 21	52, 65	S/G*	VGRID
D	Mixed	50, 59	120, 139	JAXA	JAXA tools
E	Mixed	52, 58	107, 120	O/BC**	ANSA

Blue=no nacelle/pylon

Red=with nacelle/pylon

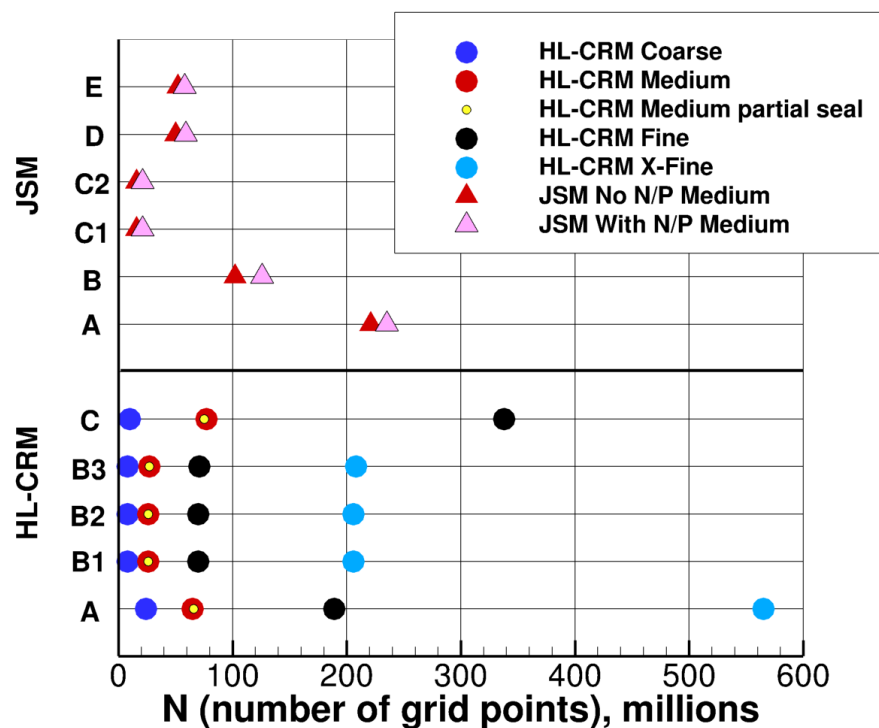
\* Spaceship Company and Gulfstream Aerospace Corporation

\*\* University of Oxford and BETA-CAE Systems S.A.

# Grid Sizes

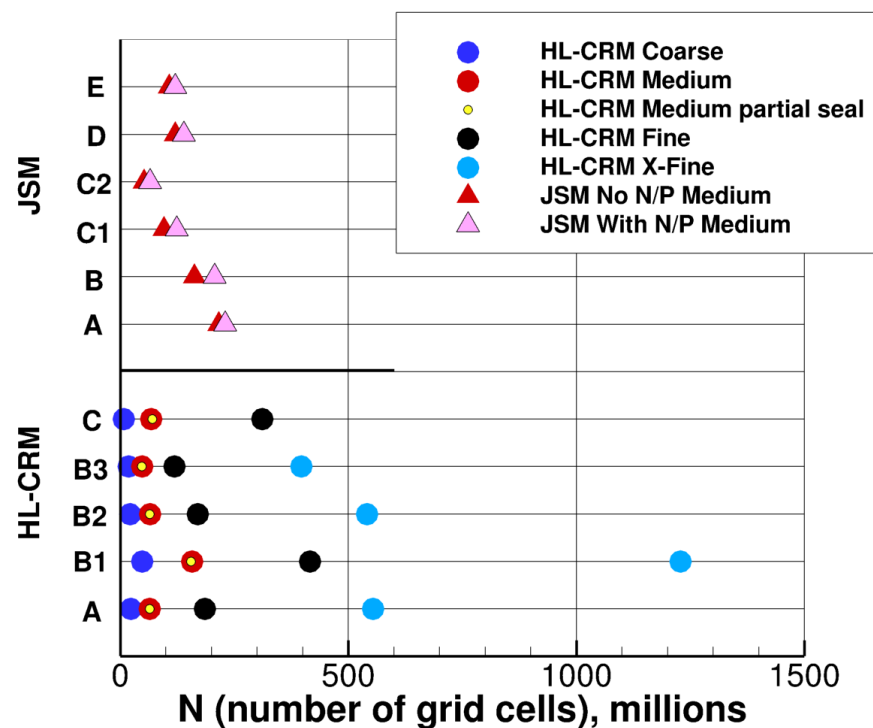
## Number of Points

HiLiftPW-3 Committee Grids

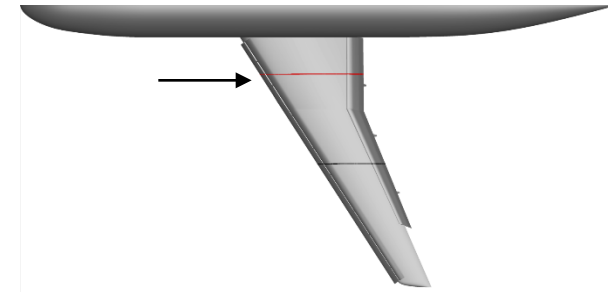
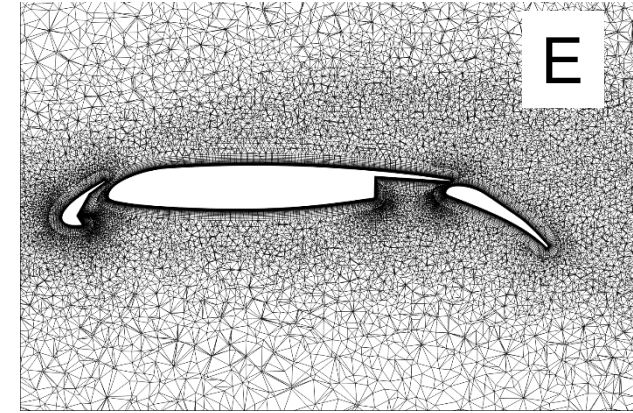
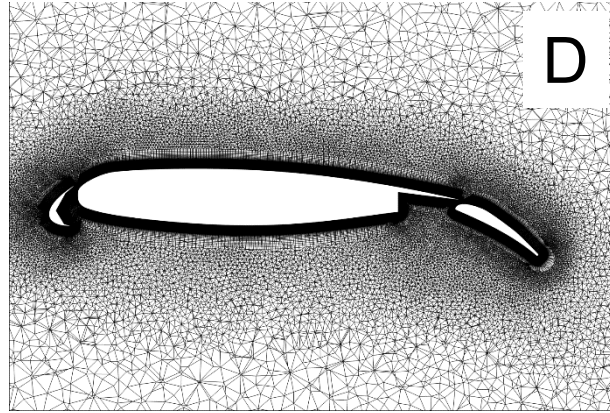
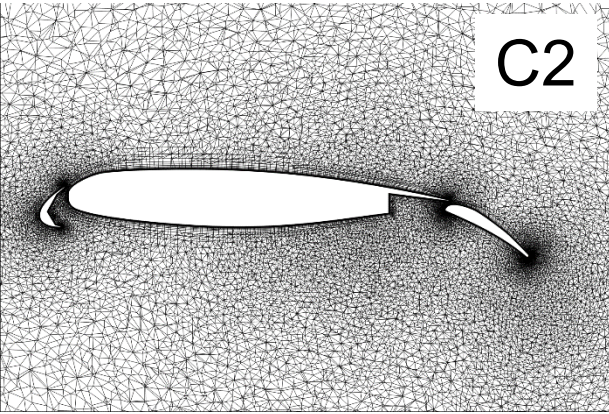
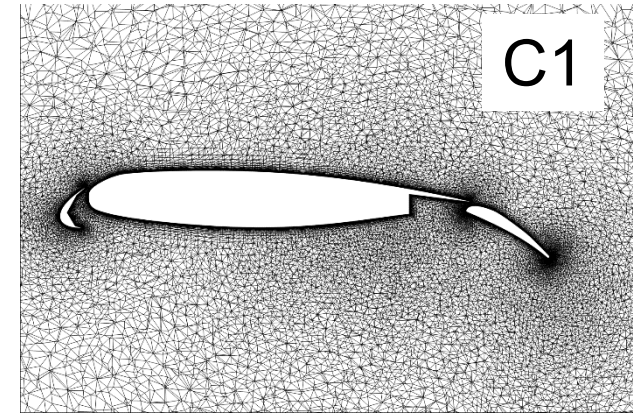
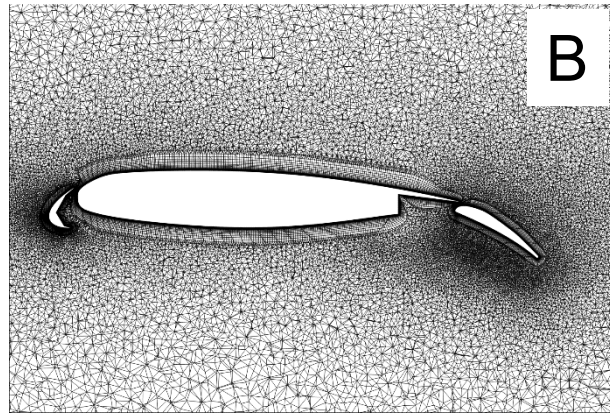
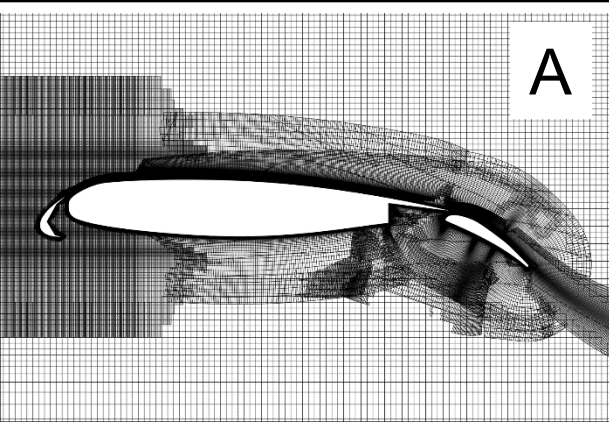


## Number of Cells

HiLiftPW-3 Committee Grids

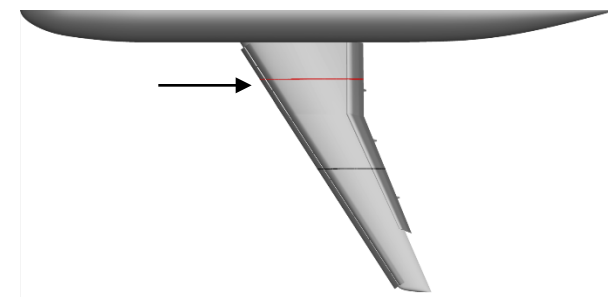
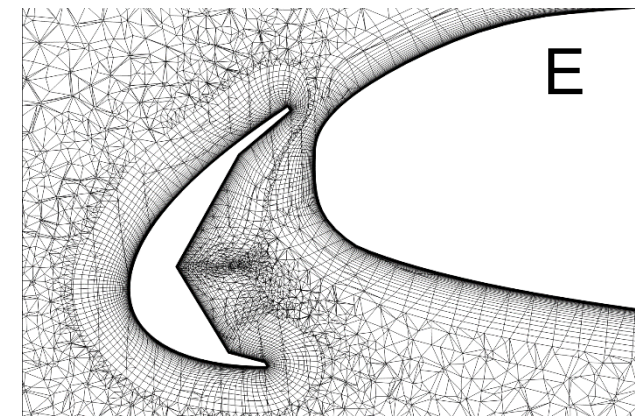
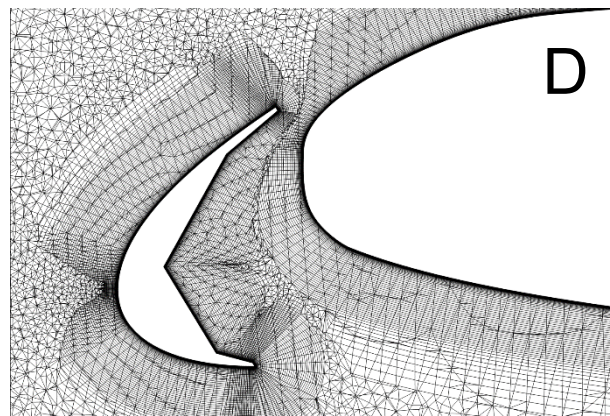
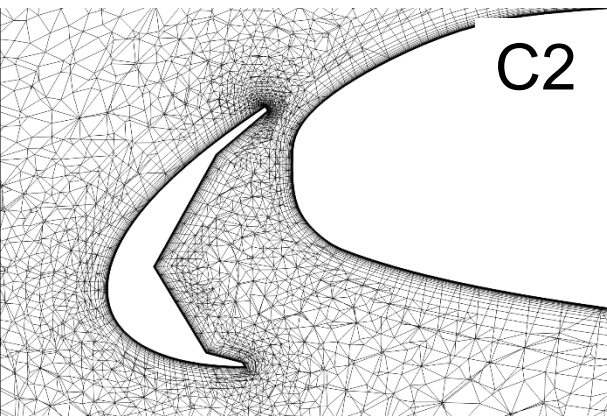
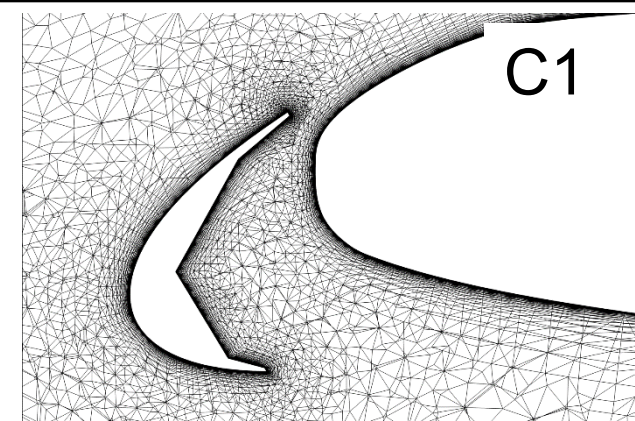
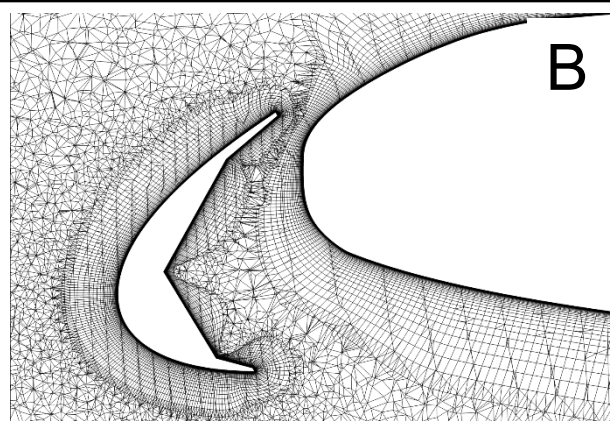
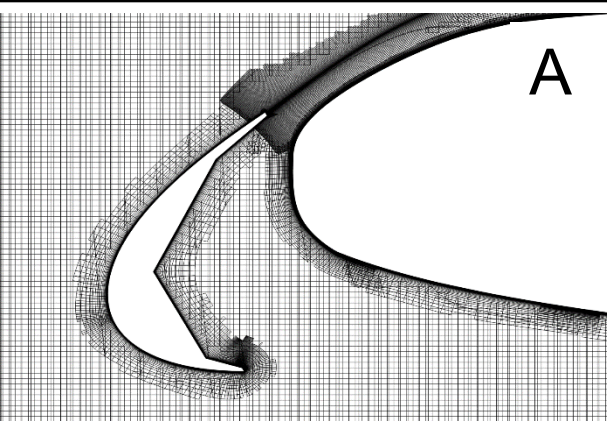


# JSM – High Lift system detail (grid)



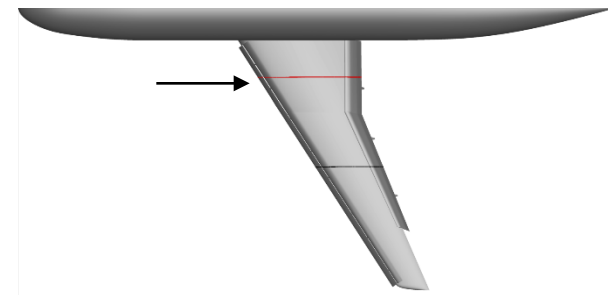
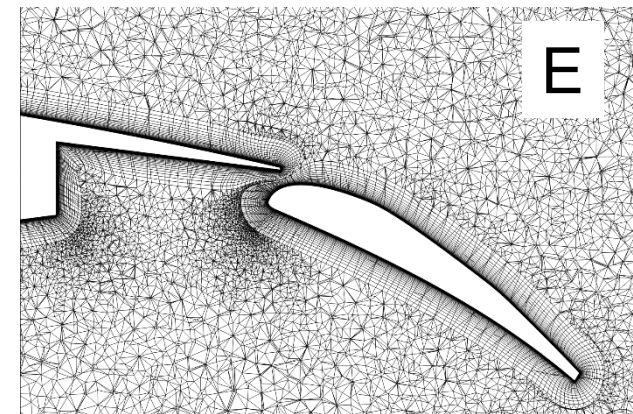
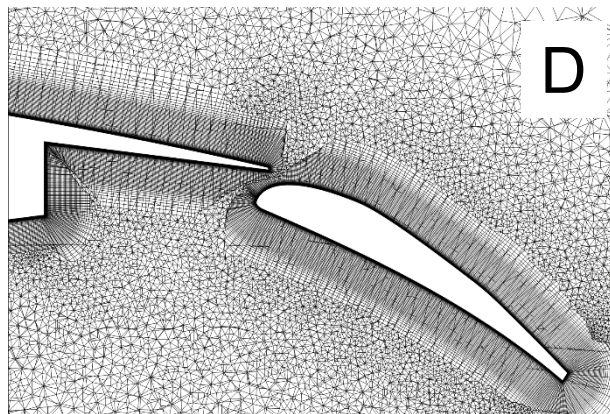
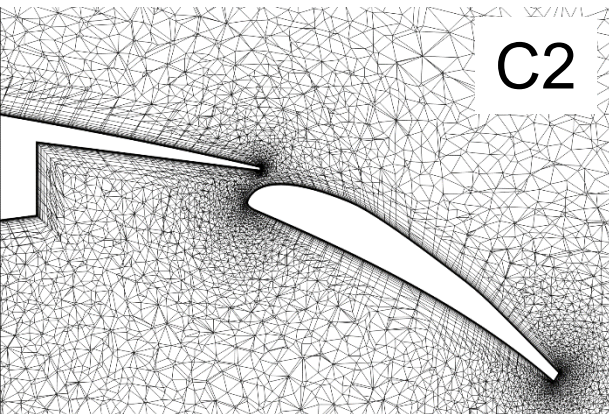
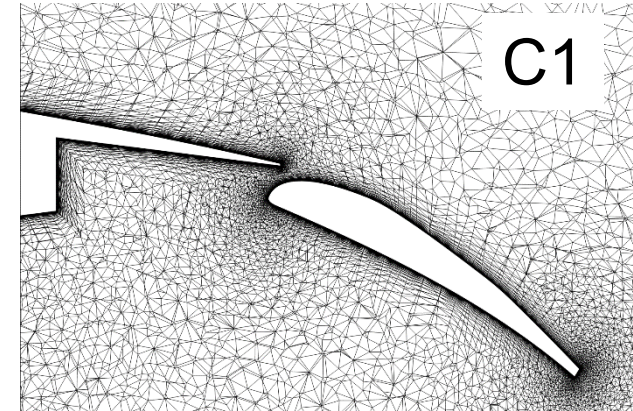
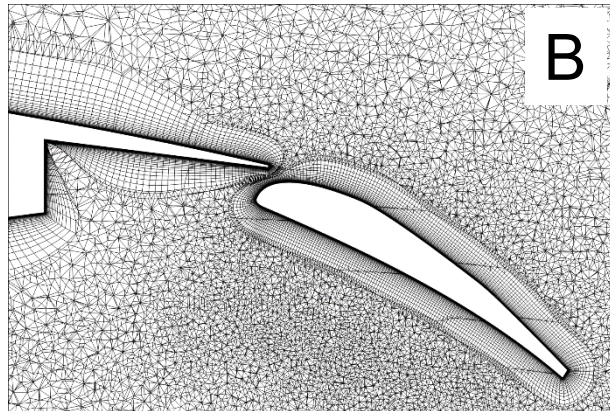
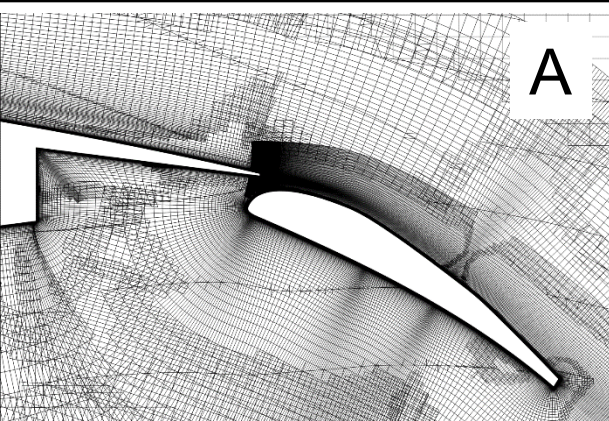


# JSM – Slat detail (grid)



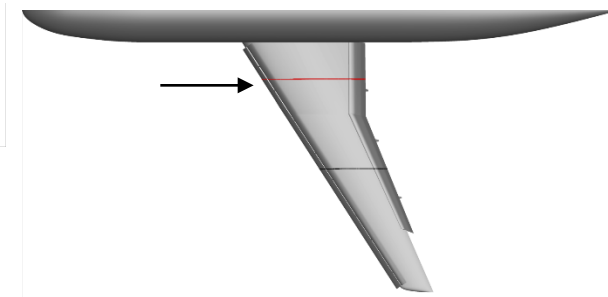
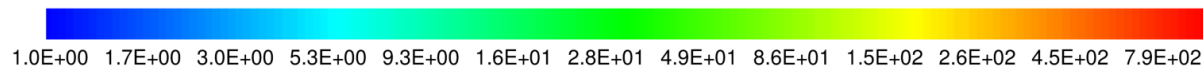
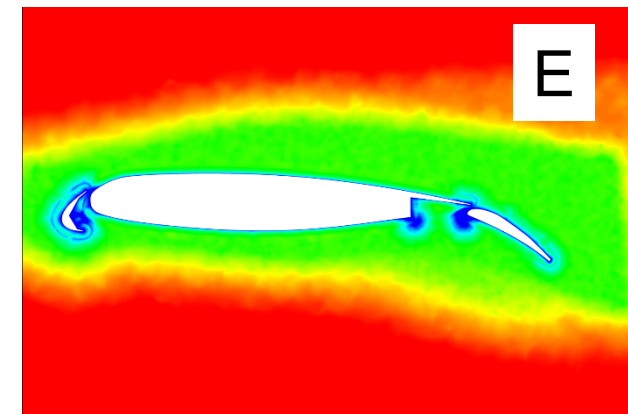
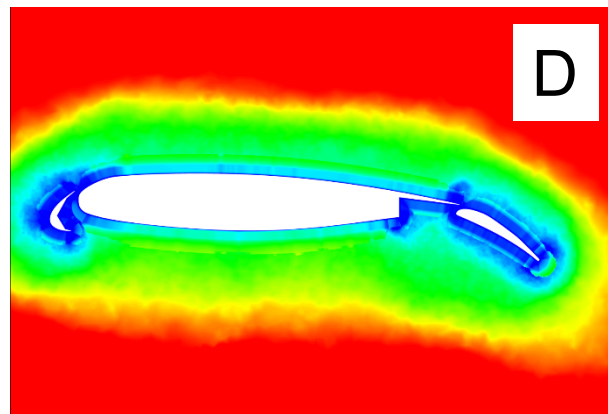
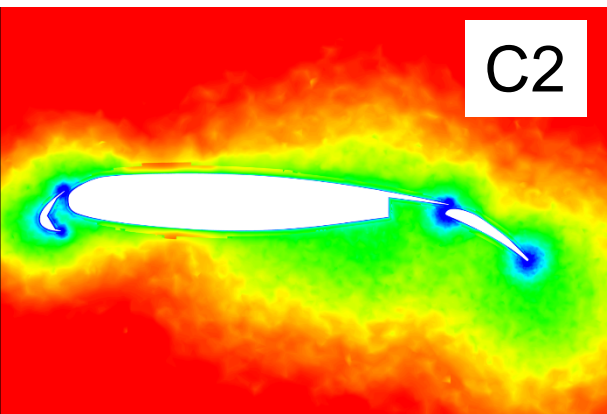
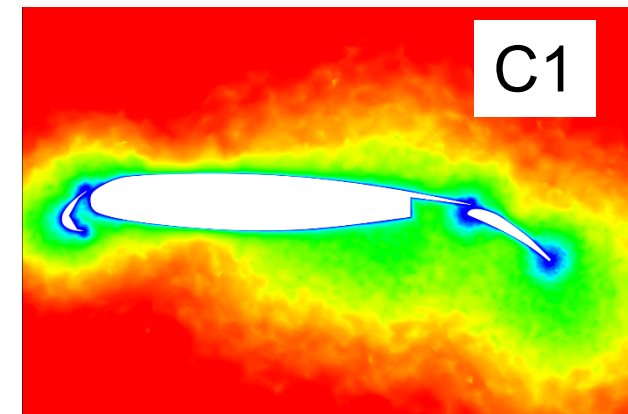
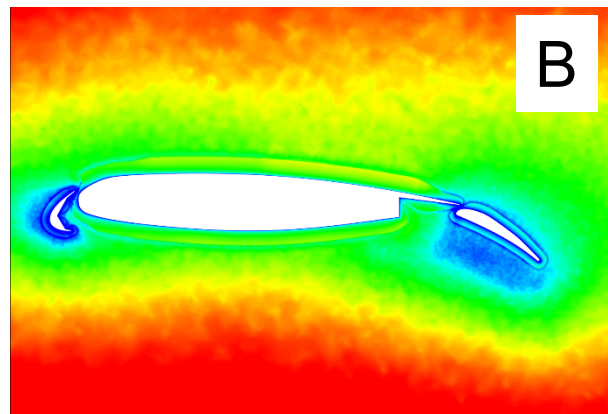
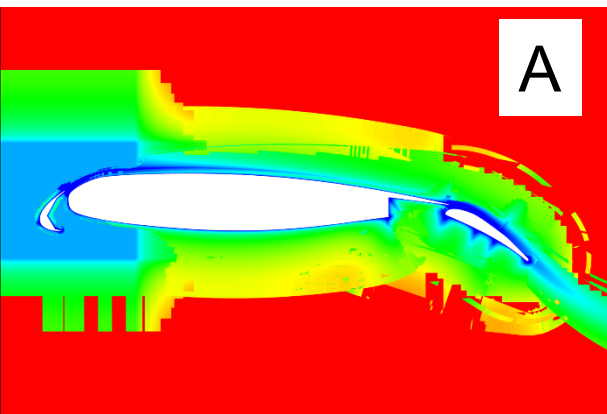


# JSM – Flap detail (grid)





# JSM – High Lift system detail (cell volume)



- **Chicago 2010 – HiLiftPW-1**
  - SPECIAL SESSIONS – Orlando 2011
  - SPECIAL SESSIONS – New Orleans 2012
- **San Diego 2013 – HiLiftPW-2**
  - SPECIAL SESSIONS – National Harbor 2014
  - SPECIAL SESSIONS – Atlanta 2014
- **Denver 2017 – HiLiftPW-3**
  - SPECIAL SESSIONS – (PLANNED) Kissimmee 2018
  - SPECIAL SESSIONS – (TBD) Aviation 2018
- **TBD – HiLiftPW-4**

- Two 6-paper special sessions planned for SciTech 2018
  - Summary presentation (1 hr)
  - HiLiftPW-4 discussion (length?)
- Objective of these sessions is to analyze participant data in more detail and to share additional insights with CFD community
- The HiLiftPW Committee has received too many requests, and needs more time to determine how to organize the sessions.



# Acknowledgments

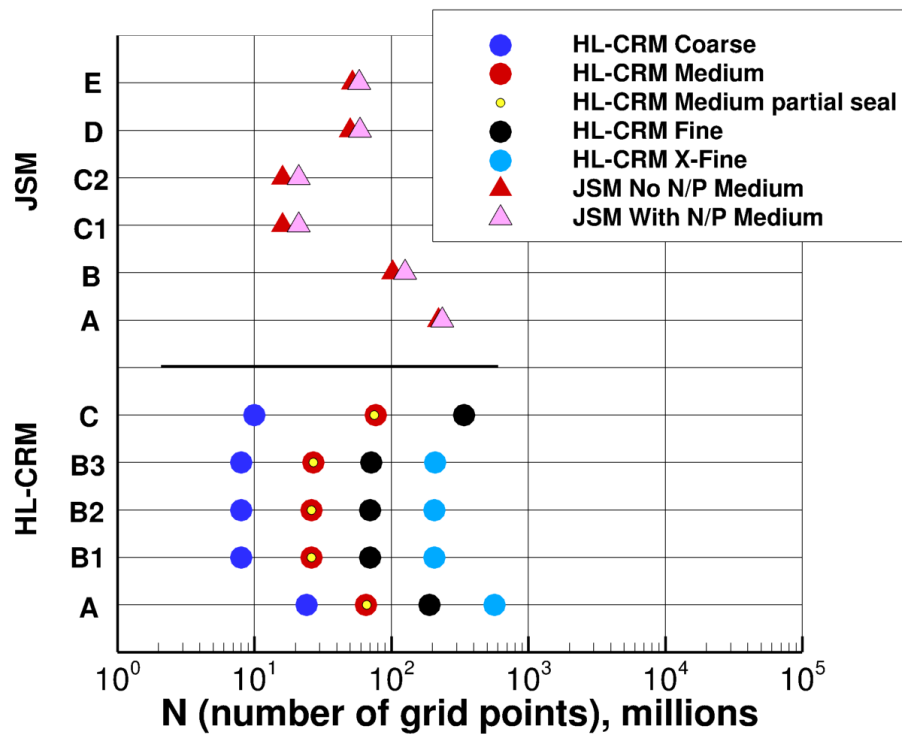
- **AIAA Applied Aerodynamics Technical Committee**  
Carl Tillman, Khalid Abdol-hamid
- **AIAA Conference Planning Staff**  
Megan Scheidt, Alexi Thomas
- **NASA Fundamental Aeronautics Subsonic Fixed Wing (SFW)  
Aerodynamics Technical Working Group (TWG)**  
Mike Rogers, Scott Anders

# Back-Up

# Grid Sizes (log scale)

## Number of Points

HiLiftPW-3 Committee Grids



## Number of Cells

HiLiftPW-3 Committee Grids

